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Landslide Measurement in Glendroud Region (From the Central Part of Noor City) in Mazandaran Province Iran by Using Remote Sensing and Radar Interferometry Techniques

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Studying and monitoring the amount of displacement caused by changes in the shape of the earth's surface is one of the important and practical studies in various topics of geology and geophysics, which plays a significant role in the prevention and behavior of natural disasters such as earthquakes, subsidence, and landslides. Among them, there are various methods for geodetic measurements and monitoring of these deformations, among them the radar interferometric technique with the capabilities of producing wide, frequent and continuous ground covers, as well as high temporal and spatial resolution, is one of the techniques has become important

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and significant. Landslides in the Yilagh area of GlenrodRoyan, Noor city, caused a lot of damage to some residential areas, gardens and roads of several villages in the region. Due to the movement of the earth, water and electricity have been cut off in some areas. About one kilometer of the north-south road has been destroyed and the most damage has been done to the houses of Foulad welfare complex. After passing through a long period (more than 60 years) of drought, the country of Iran has faced various risks in recent years, especially in 2018 and 2019, including floods and landslides. The aim of this thesis is to obtain the amount of displacements caused by the landslide in Glenrod region in 2019 using sentinel-1 satellite images by using the differential radar interferometry method using snap software. In this regard, from 4 satellite images It has been used during the years 2019-2020, and according to the results obtained, the largest landslide during the second period was 15 cm, which is based on the information obtained from the mapping organization and the opinion of geologists and experts in the region who stated that the largest displacement in area under report was March 2019 and it matches with the findings carried out by the present authors.

Keywords: Glandrod; differential interferometry; remote sensing; landslide.

1. INTRODUCTION

Since the early 1990s, combined aperture radar interferometry has been proposed and used as an efficient tool in the study of all phenomena that cause displacement of the earth's surface. Radar interferometry, by using the phase difference of two or more radar images, seeks to estimate the amount of deformation and displacements caused by land subsidence, landslides, as well as natural disasters and the production of the elevation model of the earth. This technique was used for the first time in 1986 to produce a topographic map, and then it was used in various applications such as calculating the displacement caused by earthquakes, studying volcanoes, investigating subsidence and uplift caused by the activity of underground faults [1–4]. One of the geomorphological phenomena that affects many human activities is the occurrence of landslides. Natural factors on the one hand and human activities on the other hand cause these incidents [5]. Landslides are one of the most important natural hazards and active processes that lead to erosion and changes on the earth's surface [6]. Today, there is a need for processes to manage landslide risk in a quantitative way and its zoning. Iran has mainly mountainous topography, high tectonic and seismic activity, diverse climatic and geological conditions, mainly natural conditions for a wide range of landslides [7,8]. Lin et al. [9] investigated landslides in the La Paz region of Bolivia by using permanent scatters. In the research, Sentinel-1 images were used. The results of the research showed that there are several landslides in the region. Whose displacement rate reaches 15 cm per year. Mass movements are among the geomorph-dynamic phenomena that occur under the influence of various factors on the slopes of mountainous areas, and the most important of them is landslides in different forms. Landslides can be thought of as the movement of a mass of rock, debris or a part of the earth in the direction of the slope of the slope [11,10]. This state is related to the areas where the shear stress of the material is higher than its shear resistance and it is called domain instability. According to preliminary estimates, about 500 billion riyals of financial losses are caused by landslides in our country every year [12]. Iran is considered a high-risk country due to unfavorable geographical conditions, weak comprehensive management and non-compliance with environmental thresholds. Therefore, in areas where the risk of landslides is high, mapping methods are very necessary to accurately assess the location of slope fractures and the size of landslides, as well as to estimate the activity level in their displacement characteristics. In the beginning, the identification of landslides was mostly based on the visual interpretation of stereo pairs of aerial photographs and through field observations. However, the visual interpretation of aerial photographs in combination with field surveys has remained one of the main sources in landslide mapping until today [13]. In the last decade, with the adoption of GPS tools, the possibility of monitoring landslides with the purpose of behavior measurement was considered, but in recent years, the InSAR radar remote sensing technique, which has the ability to work in all weather conditions and throughout the day and night, including It is considered effective and efficient techniques in monitoring slow changes of the earth's surface. In such a way that this method, having a wide ground coverage and a high temporal and spatial separation power, is one of the most accurate in millimeter scale and the least expensive remote sensing techniques in identifying the displacements that have occurred on the surface of the earth has been used [14]. The simplest method in this field is to use the minimum d and the image obtained from radar sensors with an artificial aperture as an interferometer [3]. According to the recent advances in the InSAR radar interferometric technique, many researches have been carried out in the field of landslide detection and monitoring. Castaneda (2009) in an article titled DInSAR measurements of land surface changes caused by land subsidence due to pits, mining and landslides in the Iber River and Spain, 29 ERS radar image frames from From 1995 to 2000, using differential interferometric technique using SBAS method, he analyzed and revealed the size and extent of displacements in the range of transformation. Coherence in agricultural areas, most active pits occur in flood plains and lower terraces, which are mainly dedicated to irrigated agriculture.In 2017, Nikola et al. analyzed InSAR data for the displacement of landslides using L-1 Sentin data in the northeastern slopes of Kup and in the city of Isai, Romania. Finally, they came to the conclusion that Issa region is under the influence of slow landslide movements, which makes the study area a suitable place to investigate and evaluate the above techniques. Based on the results obtained in the Qab-Latuhhi part of the region, the displacement speed was more than 1 mm per year. These values showed the average speed of the satellite line of sight and the displacement process of the earth's surface during the study period [15]. 1385 Raushit has studied the surface displacement caused by the Fin earthquake in southern Iran in 2006 using radar satellite images using radar interferometric technique. While determining the values of vertical and horizontal displacement caused by the above earthquake, he stated that due to the dry conditions of the country, interferometer images have a high correlation with radar images [16]. Undoubtedly, the role of differential radar interferometry with an advanced composite aperture is very significant in the field of landslide monitoring. A research has been done to evaluate the quality of data obtained from radar interferometry with a combined aperture, such as combining different satellite data with ground data. The satellite radar interferometry technique is a suitable method for monitoring large areas affected by landslides, while radar interferometry with ground composite aperture is efficient for continuous monitoring of small areas. Among the optical sensors, ground imaging is a powerful and relatively inexpensive tool, with ease of installation and suitable for permanent monitoring.

2. STUDY AREA

Glendrud deposit is located in the northern slope of Alborz mountain range in Mazandaran province. The center of the field has an east longitude of 51degrees to 52 degrees and a north latitude of 30degrees to 36 degrees, located in the geological quadrant of Amol. The area is connected to the Caspian coast through the Royan road, through the Kejur road to the Kandavan road, and through the newly constructed Beledeh road to the Haraz road. The largest city in the region is the center of Noor city, which is located twenty kilometers northeast of the region. The nearest railway station to Glenrod is in GhaemShahr, which is 127 kilometers away. The most populated places in the region are the villages of Glenrod, Pimod, Lashkanar, Mianrodbar and Vazak. The minimum altitude of the area is 500 meters and the maximum is 1800 meters. The area with thick forest cover is one of the greenest areas in the north of the country. The occupation of most of the people in the region is animal husbandry, and some of them are also engaged in forest work, wood procurement and transportation. In terms of climate, the area in question is influenced by the sea from one side and the Alborz mountains from the other side, so that up to the height of 600 meters, the area has a mild and humid climate, and in other areas, it has a mountainous climate with cold winters and Summers are relatively cool d. Glendrud River, which is located in the south of the region, drains most of the water caused by seasonal rains [17].

3. MATERIALS AND METHODS

In order to investigate the landslide in Glenrod village [18], Noor city, Mazandaran province, from the radar images of the sentinel 1 sensor in IW mode, during a period of one year, even images were taken for a period of almost three months, and the amount of landslides in this area was investigated. The reason for choosing this period of time was the biggest and most noticeable landslide in this area, which left a lot of damage. In the following, the full information of the pairs of images and calculation periods are given in the Table 1.

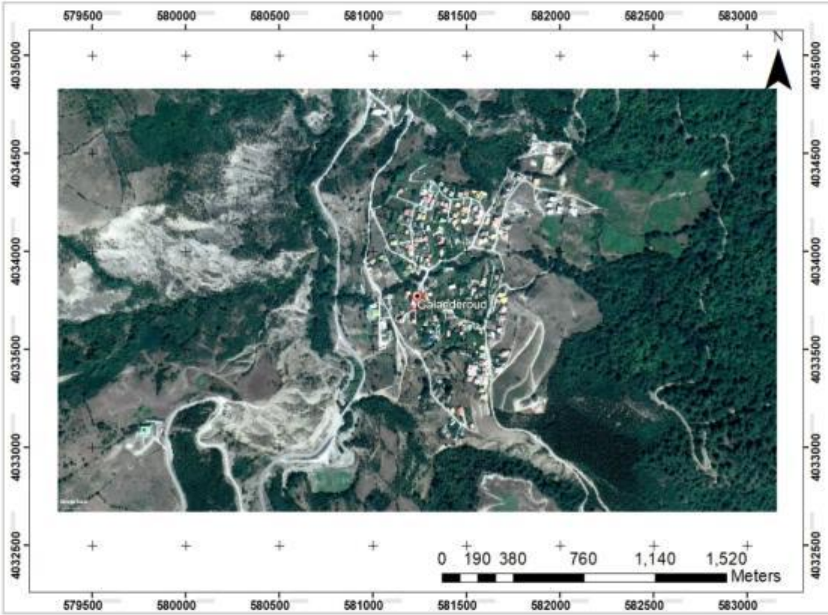

Fig. 1. Study area

Table 1. Information about the taken images

Polarization	Transient polarization imaging	Imaging MOD	Imaging format	Date of Imaging	Number
VV	ISDV	IW	SLC	2019/08/31	1
VV	ISDV	IW	SLC	2019/17/12	2
VV	ISDV	IW	SLC	2020/03/22	3
VV	ISDV	IW	SLC	2020/07/08	4

In this research appropriate sentinel-1 satellite images used after selecting pairs of radar images for radar interferometry production of interferogram have been, done after removing the topography effect and applying the adaptive filter and generating the coherence image, phaseunwrapping finally detection of landslides is done and then with D-INSAR technique process had been done in Snap.8 software.

3.1 Sentinel-1

The Sentinel 1 satellite is the first satellite of the Copernicus program, which is managed by the European Space Agency. This mission consists of Sentinel 1A and Sentinel 1B satellites that have the same orbit.ESA or European Space Agency and European Union policies have made Sentinel-1 data readily available [19]. Many users can obtain the data and use it for public, scientific or commercial purposes for free. Data from 4 time periods determined by the European Space Agency for free via the Copernicuswebsite has been downloaded [20].

3.2 (IW) Mode

One of the most important and practical modes is Sentinel-1 sensor imaging, which is used in the field of radar interferometry. This imaging mode consists of three sub-swaths covering a 250 km range on Earth. The spatial resolution in this mode is 5 x 20 meters and uses the TOPSAR technique for imaging. In the TOPSAR technique, the measuring antenna rotates in the azimuth direction and picks up a series of bursts to form sub-swaths. A burst is a series of overlapping bands that form a sub-swaths. Therefore, the images formed with IW mode include three sub-swaths, each of these sub-swaths consists of 6 to 10 bursts [21].

3.3 SNAP Software

All stages of radar interferometry processing in SNAP software. 8 under the Windows operating system, which is provided to users for free by the European Space Agency. SNAP software stands for Sentinels Application Platforms as an open source software for processing Sentinel series satellite data. This open source software, which was designed by the European Union Space Agency, effectively and efficiently provides the ability to perform various specialized processes of Sentinel series satellites along with radar data. One of the important and practical parts in processing Sentinel 1 radar images with SNAP software is the possibility of preparing graphs. Also, in this software, there are a number of suggested graphs for processing radar images, which can be changed by the user [17] .Our final output in this software is the final rapped phase, which shows the depressions and elevations of the area, and in the last step, to get the final output, we have to convert the obtained phase into displacement.

3.4 D-INSAR (Differential Interferometry Synthetic Aperture Radar)

The technique of radar interferometry (D-INSAR) is a suitable method to detect changes in the earth's surface. The calculation of the displacement occurred on the surface of the earth using the D-INSAR technique includes unique capabilities in terms of cost, time and accuracy compared to other remote sensing techniques.

One of the most basic steps in the processing of radar interferometry is the selection of a pair of radar images. Several factors such as sensor frequency, spatial baseline, time baseline, and spatial overlap in the direction of the sensor's movement are effective in selecting a pair of images. A pair of radar images has interferometric potential when the redistribution of energy returned from the ground surface is covered by at least two antennas or the common area is present in at least two radar images [22].

4. RESULTS AND DISCUSSION

4.1 Selecting Pairs of Radar Images for Radar Interferometry

One of the most basic steps in the processing of radar interferometry is the selection of a pair of radar images. Several factors such as sensor frequency, spatial baseline, time baseline, and spatial overlap in the direction of sensor movement are effective in selecting a pair of images. A pair of radar images have interferometry potential when the redistribution of the energy returned from the earth's surface is covered by at least two antennas or the common area is present in at least two radar images. The difference of the satellite path in two passes must be less than a certain amount, which is called the critical space length. If the amount of normal gap length exceeds the critical gap length, the lack of spatial dependence occurs and makes interferometry impossible.

The next factor is the time baseline. In this way, with the increase in the time of taking two images, the possibility of changes in the ground targets has increased, which is due to the fact that each pixel of the image consists of an infinite number of particles. And the electromagnetic characteristics of each of these scattering particles and their position relative to each other will be different in time, as a result, the probability of signal dependence between two images is reduced, which itself causes an increase in noise in interferometry. The spatial overlap of two images should be more than 70% [23].

4.2 Interferogram Production

After matching the two images, the phase obtained from the two SLC images is differentiated with respect to each other and an Interferogram is produced. The phase resulting from the possible movement of the Earth's surface crust includes phases related to topography, the phase added as a result of orbital changes, and the phase related to atmospheric disturbance. That in the continuation of the Interferometric processing process, all other phases must be removed from the surface of the resulting interferometer. Refer to the Figs. 2, 3 and 4.

4.3 Topography Effect Exclusion

Before removing the topographic effect, all the parts in the image must be connected together to process it as a single image, which is called De-burst, then by the Topographic phase removal command and using DEM. 32 meters ResolutionSRTM, the effect of topography is removed from the facade interference. In fact, the software performs this action by simulating an interference view from the DEM of the area and subtracting it from the interference of the processed view. The resulting product will be an interferometer with the topography effect of one band removed for the integrated topography phase. so it demonstratedin Figs. 5, 6 and 7.

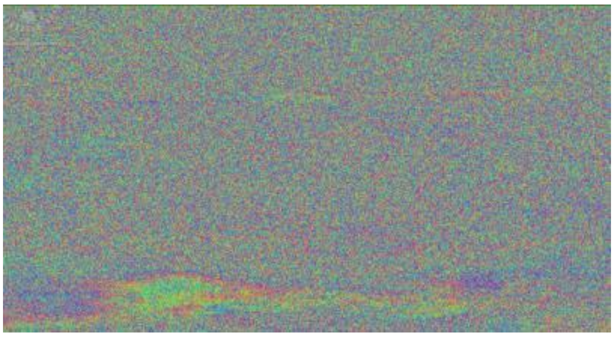

Fig. 2. Interference of the first image pair view

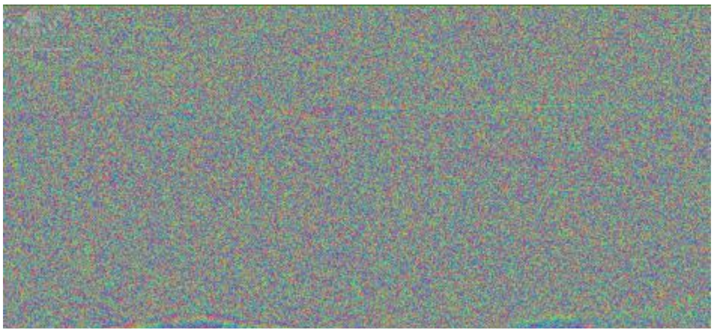

Fig. 3. Interference of the second image pair view

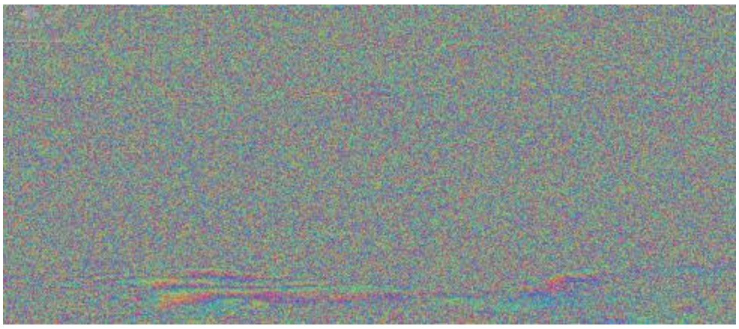

Fig. 4. Interference of the third imagepair view

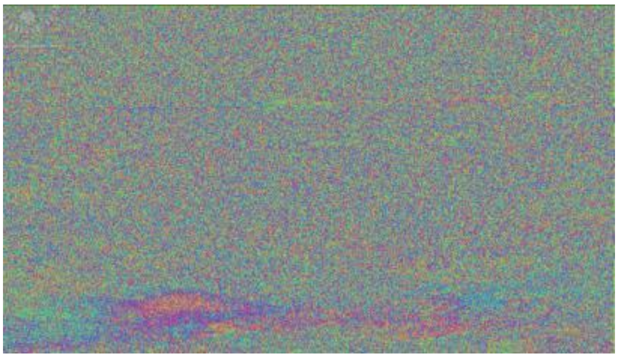

Fig. 5. Topography effect exclusion of the first pair images

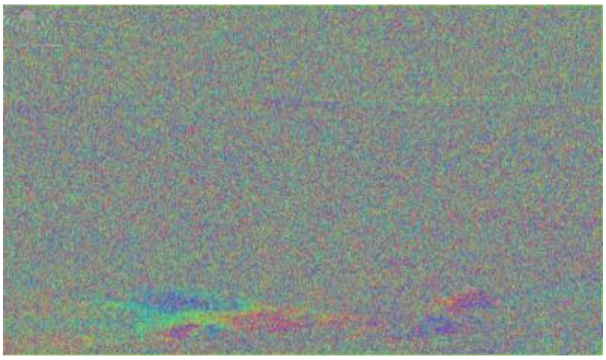

Fig. 6. Topography effect exclusion of the second pair images

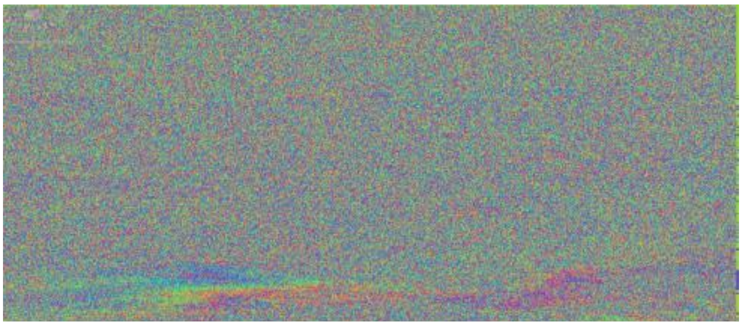

Fig. 7. Topography effect exclusion of the third pair images

4.4 Applying Adaptive Filter and Generating Coherence Image

The result of this process, while removing the noise from the phase related to the displacement and improving the visual quality of the interferometer fringes, will also lead to the production of a coherent image, this image in turn is a good indicator of the quality of the interferometer and its suitability to continue the interferometric processing process. Goldstein filter is adjusted by using the bandwidth variable which is obtained directly from the correlation of the spectral power of the differential interferometer. In this way, it works in areas with high correlation with low bandwidth or limited number of pixels and in areas with low correlation with high bandwidth and more pixels.

The coherent image is obtained from the power correlation of two coordinated SAR images, which represents the correlation index of signal power values in two images taken at two different times. The coherence value varies from 0 to 1, and this value is a coefficient that measures the reliability of the measurement. In this case, a window is used on the main image and its corresponding window on other images. If each pixel has the same phase as its corresponding pixel, this amount has a value equal to one, if the amount is equal to zero, it means that the measurement is meaningless. The coherence thus depends on the dimensions of the window. In general, if the value of this index for a pair of images used in interferometry is low, it means that that pair is not very suitable for interferometry. Results shown in Figs. 8, 9, 10.

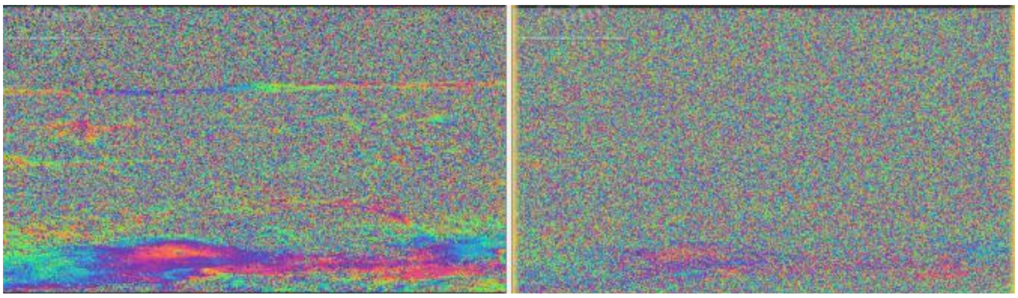

Fig. 8. Applying the Goldstein filter of the first pair image

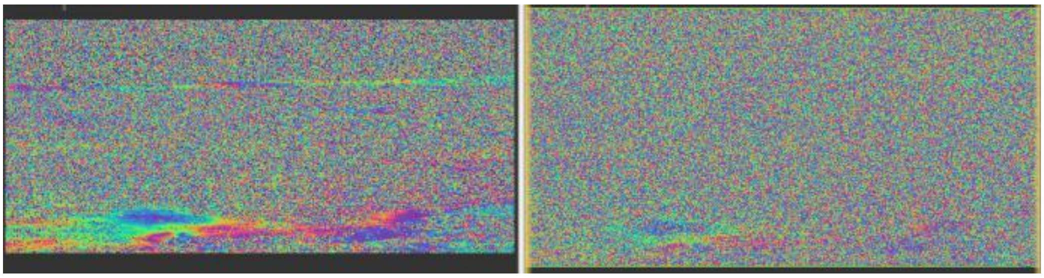

Fig. 9. Applying the Goldstein filter of the second pair image

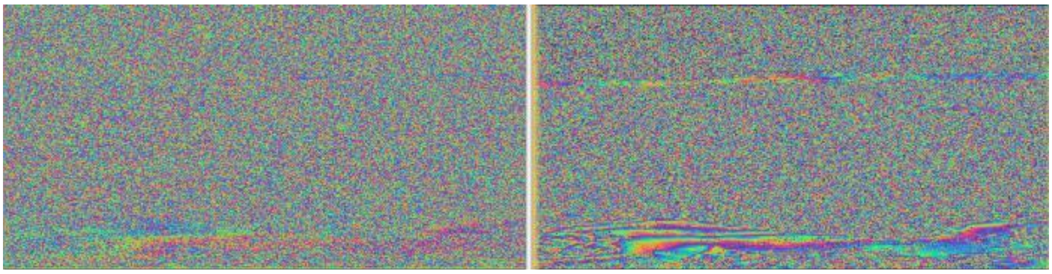

Fig. 10. Applying the Goldstein filter of the third pair image

4.5 Phaseunwrapping

From the phase difference obtained in the phase correction phase from the phases caused by topography and orbital errors, the absolute phase is obtained, which is related to the displacements of the event on the ground during the time interval of taking two radar images. Sudden changes or phase jumps in the phase corrected image of the previous stage are removed and the phase values show smooth and gradual changes. What is certain is the sudden and relatively severe change of the earth's surface, except for cases of faulting, it is impossible to a large extent. Therefore, any sudden shift of phase values from the control and investigation of geological and morphological structures, and especially the issue of surface changes of the earth's crust, should be attributed to phase jump and corrected. By processing this pair of images, we came to the conclusion that in the second time period, we have the most movement, which corresponds to the information in the geological site of this area.

4.6 Detection of Landslides

Using the image obtained from differential radar interferometry and filtered interferometer, the displaced areas were identified in the form of landslides, and in order to control the identified areas, field survey using GPS and images available in Google-Earth were used.

4.7 The Results of the Transfer Rate of the First Course

The first result of the amount of displacement for the period of 108 days from 31/8/2019 to 17/12/2019 was calculated d. According to this study, the amount of positive displacement or in other words, landslides from green to yellow is 1.0 to 13.00 it shows slip d. But for the period of 108 days and the location of the landslide, which mostly happened in Glendrud area and its surroundings, the number of 5.05 meters can be significant.

4.8 The Results of the Transfer Rate of the Second Semester

The second result of displacement amount was calculated for the period of 204 days from 8/31/2019 to 03/22/2020 d.

According to this survey, the amount of positive vertical displacement or in other words, the landslide of 10/10 meters or 10 cm indicates the landslide. Although this amount of landslides is considered insignificant, it can be significant for this region, which is mostly at risk of landslides. According to the studies conducted, the cause of this landslide could be the long-term rains of 1998, the saturation of the underground water and soil in this area, and the lack of implementation of the appropriate underground and surface drainage plans.

According to the experience of several stages of thrusting in this region from the past decades until now and the heavy rains of recent years, it has caused the breaking of various fracture surfaces and the displacement and confusion of the vast thrusting area.

4.9 The Results of Displacement Rate of the 3rd Period

The third result of displacement amount was calculated for the period of 12 months from 8/31/2019 to 7/8/2020 d.

According to this survey, the amount of vertical displacement is about -04093 meters or 4 cm. The results can be seen in the Fig. 15.

Finally, according to the numbers obtained from the differential radar interferometric method and comparing the results of the 3 investigated periods with the information of the mapping organization, for the first period the displacement was 5.42 cm, for the second period the displacement was 7.37 cm. cm, and for the third period they have obtained 8.59 cm, you can understand the accuracy and correctness of the work done in this thesis.

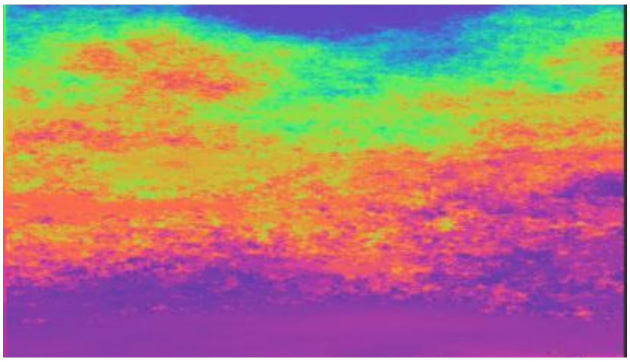

Fig. 11. The unwrapped phase of the first period of Snap software

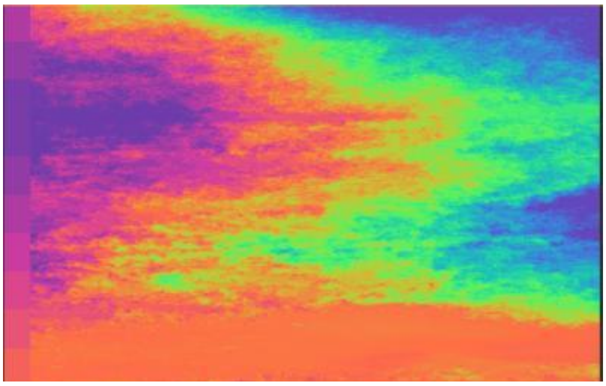

Fig. 12. The unwrapped phase of the second period of Snap software

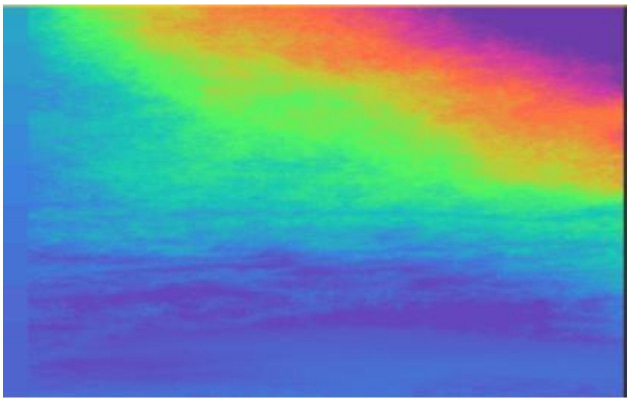

Fig. 13. The unwrapped phase of the third period of Snap software

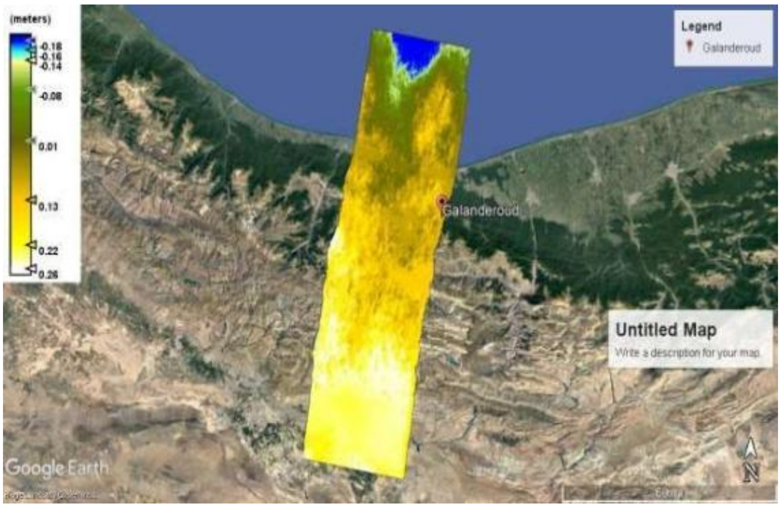

Fig. 14. Vertical displacement of the first period

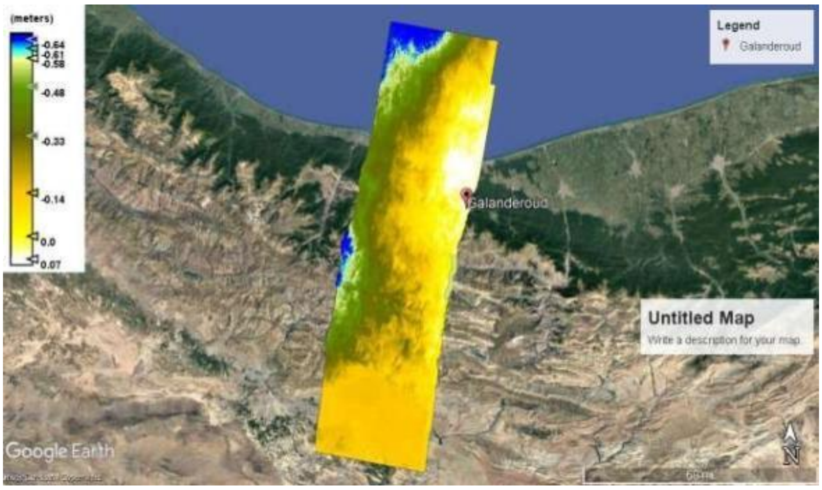

Fig. 15. Vertical displacement of the second period

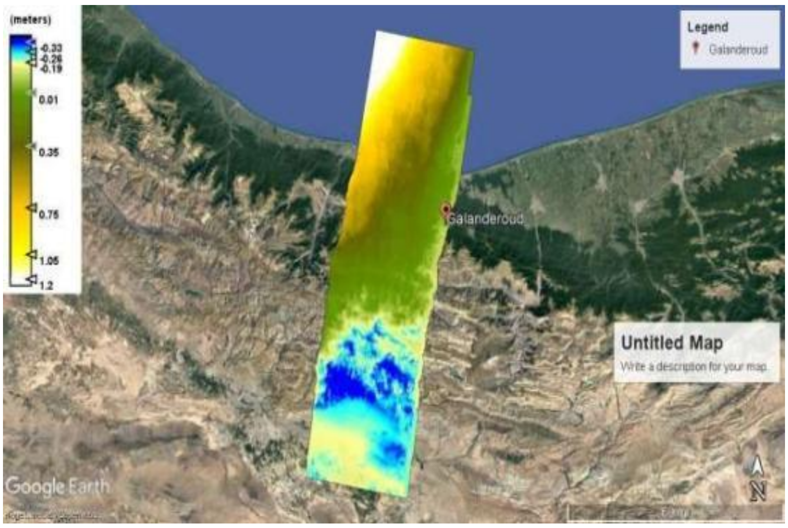

Fig. 16. Vertical displacement of the third period

Table 2. Coordinates of checked points

Longitudes	latitudes	Displacement
51°54´30˝	36°26´40˝	/0508
51°54´30˝	36°26´40˝	/1028
51°54´30˝	36°26´40˝	-/04039
51°54´16˝	36°26´30˝	5/42
51°54´38˝	36°26´04˝	/0737
51°55´28˝	36°28´21˝	-/0859

5. CONCLUSION

Landslide in area of GlendroudRoyan of Noor city caused great damage to some residential areas, gardens and roads of several villages in the area. Due to the movement of the earth, water and electricity have been cut off in some areas. About one kilometer of the road from north to south has been destroyed and the most damage has been done to the houses of RefahYefolad complex. The change of long heavy rains of 60 to 70 hours, changes in land use and large areas of natural and national resources in the past few decades and the special situation of geology, geomorphology, soil science of Iran and the lack of attention and expenditure It is necessary to protect soil and water especially in Mazandaran province, one of the main and important reasons for the occurrence of dangerous landslides.

6. FUTURE CHALLENGES

- ✓ Due to the free and availability of 1-SENTINEL images and also the characteristics of the data, it is recommended to use 1-SENTINEL sensor data to examine the movements of the earth's crust.
- ✓ In case of obtaining long time series data (a large number of images from one pass) the accuracy of interferometry can be increased with more checks.
- ✓ It is recommended to do the same thing for radar images of other satellites, especially radar imaging satellites that have images with higher resolution, such as TerraSAR-X and ALOS satellite images or other radar satellites.
- ✓ It is suggested to use the images in the upper and lower passes to further investigate the landslide in this area.
- ✓ In a one-year period, the rate of landslides in the Glendroud Noor area was investigated and the high-risk areas of this area were identified using satellite image processing, but due to the heavy damage caused by landslides in this area, it is recommended to choose a longer time frame for Landslide investigation of the area and software processing, special geological, geomorphological, soil science, and underground reservoirs should also be investigated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dehghani A, Hojati H, Shamsizadeh M. The effect of peer-led education on depression of multiple sclerosis patients. Iranian Journal of Psychiatric Nursing. 2013;1(1):63-71.
2. Hanssen R. Radar interferometry data interpretation and error analysis. Delft University Press, Delft, The Netherlands, December; 2000.
3. Massonnet D, Feigl K. Radar Interferometry and its application to changes in the earth’s surface, Department of Radar Systems Performance and Terrestrial and Department of Planetary Dynamics Centre National d’EtudesSpatiales Toulouse, France; 1998.
4. Boerner WM, Mott H, Luneburg 4E. Polarimetry in remote sensing: basic and applied concepts. Paper presented at the IGARSS’97. 1997 IEEE International Geoscience and Remote Sensing Symposium Proceedings. Remote Sensing-A Scientific Vision for Sustainable Development; 1997.
5. Bhattarai P, Tiwari B, Aoyama K. GIS aided slope instability analysis of the highway slope based on shear strength. Proceedings of 16th International Conference on Soil Mechanics and Geotechnical Engineering. 2005;2481–2484. DOI:https://doi.org/10.3233/978-1-61499-656-9-2481
6. Guzzetti F, Reichenbach P, Cardinali M, Galli M, Ardizzone F. Probabilistic landslide hazard assessment at the basin scale. Geomorphology. 2005;72(1–4):272–299. DOI:https://doi.org/10.1016/j.geomorph.2005.06.002
7. Khalidi, Sh, Darfashi, Kh. B, Mehrjunjad, A, Qarachohe, S, &Khalidi, Sh. (2012).

Evaluating the effective factors in the landslide event and its zoning using the regression model of a case study: Taleghan watershed). Geography and Risks (Logistics GIS in the Environment. Environment; Year 1. 2011;1.
8. Salehipour A. Investigating the effective hydromorphic movements in the domain movements of the watershed of Tehran University using GIS; 1380.
9. Lin CH, Liu D, Liu G. Landslide detection in La Paz City (Bolivia) based on time series analysis of InSAR data. International Journal of Remote Sensing. 2019;40:17:6775-6795.
DOI:https://doi.org/10.1080/01431161.2019.1594434
10. Cruden D, Varnes DJ. 1996. Landslide types and processes. In: Turner AK, Schuster RL . Dai FC, Lee CF, Nagai YY. Landslide risk assessment and management: an overview; 2002.
11. Karam, Abdol Amir. Quantitative modeling and zoning of landslide risk in folded Zagros, case study: Serkhon watershed in Chaharmahal Bakhtiari province. Doctoral thesis in natural geography. Tarbiat Modares University; 2008.
12. Hong Y, Adler RF, Huffman G. An experimental global prediction system for rainfall-triggered; 2007.
13. Gabriel AK, Goldstein RM, Zebker HA. Mapping small elevation changes over large areas: Differential radar interferometry. Journal of Geography Sical Research. 1989;94:9183-9191.
14. NicuşorNecula, Mihai Niculiţă, Giulia Tessari, Mario Floris. InSAR analysis of Sentinel-1 data for monitoring landslide displacement of the north-eastern Copouhillslope, Iaşi city, Romania; 2017.
DOI 10.15551/prgs.2017.85.
15. Rustae, Meh Asa. surface displacement of the 2006 Fin earthquake (south of Iran) using ENVISAT radar images, Organization of Geological and Mining Exploration of the country; 2006. WWW.GSI.ir
16. Available:www.wikipedia.org
17. Available:www.googleearth
18. Available:https://www.esa.int/
19. Available:https://scihub.copernicus.eu/dhus/#/home
20. Asgharzadeh, Hassan. Behavior measurement of landslide activity using SAR interferometric technique, Ph.D. thesis, Faculty of Geography, Tabriz University. 2013;253.
21. Alipour S, Motgah M, Sharifi M, Walter TR. "InSAR time series investigation of land subsidence due to groundwater overexploitation in Tehran, Iran." Paper presented at the 2008 Second Workshop on Use of Remote Sensing Techniques for Monitoring Volcanoes and Seismogenic Areas; 2008.
22. Available:www.ncc.org
23. Chamundeeswari V, et al. A critical analysis to generate change detection map using sar interferometry for land subsidence monitoring of new orleans city of USA. IEEE Transactions on Geoscience and Remote Sensing. 2008;518-521.

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